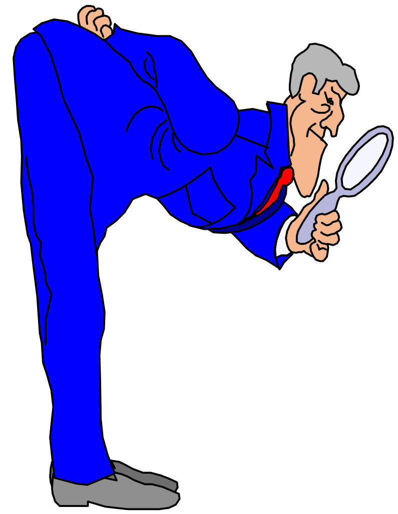
TESTING



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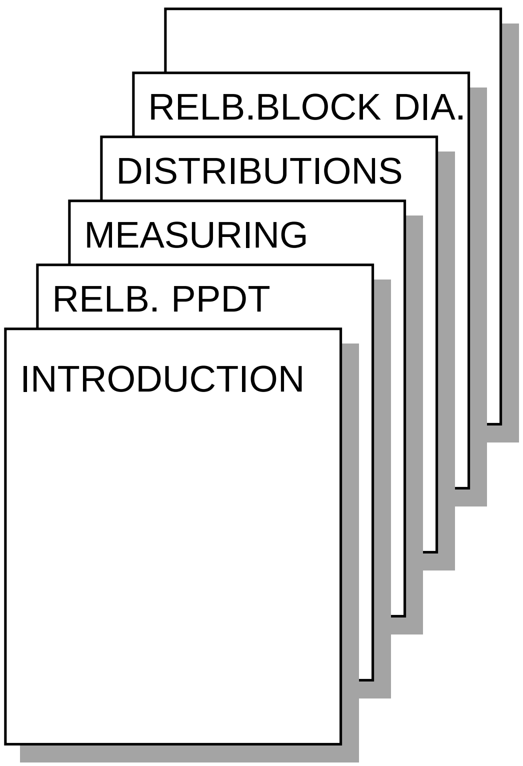
RELIABILITY TESTING:

- **Tests and analyses which are designed to measure the level of reliability of a unit and also the stability the level of reliability over time and in various environments.**

DESIGN FOR RELIABILITY

APPLICATION

BACKGROUND



ASSURANCE: RELIABILITY ENGINEERING

PHASE A PHASE B PHASE C PHASE D PHASE E

RELIABILITY MANAGEMENT---------------------------------------
MONITOR/CONTROL SUBCTR.

PROGRAM REVIEWS--
PROBLEM REPORT &COR.,LL
FAILURE REVIEW BOARDS

RELIABILITY MODELING-------------------------

RELIABILITY ALLOCATION ----------------------

RELIABILITY PREDICTION-----------------------

FAILURE MODE & EFFECT ANALYSIS--------

CRITICAL ITEMS LIST----------------------

FAULT TREE ANALYSIS-------------------

SNEAK CIRCUIT ANALYSIS--------------

ELECTRONIC TOLERANCE

MECH.PARTS ANALYSIS

PARTS PROGRAM, Using Failure Rate Data

EFFECTS TEST, STORAGE, HANDLING, etc..

TESTING: ENVIRONMENTAL

RELB. GROWTH TESTS

RELB./QUAL. TEST PROGRAM

RELIABILITY GROWTH TESTING-----
PRAT

SOFTWARE RELIABILITY & QUALITY ASSURANCE

WHY TEST?

- Reduce high development risks because of completely new design. Analyze high-risk portions of design.
- Confirm analytical models.
- Establish reliability of system.
- Gain technological information.
- Determine cause(s) of failures.
- Discover unanticipated interactions.
- Meet contract requirements or regulations.

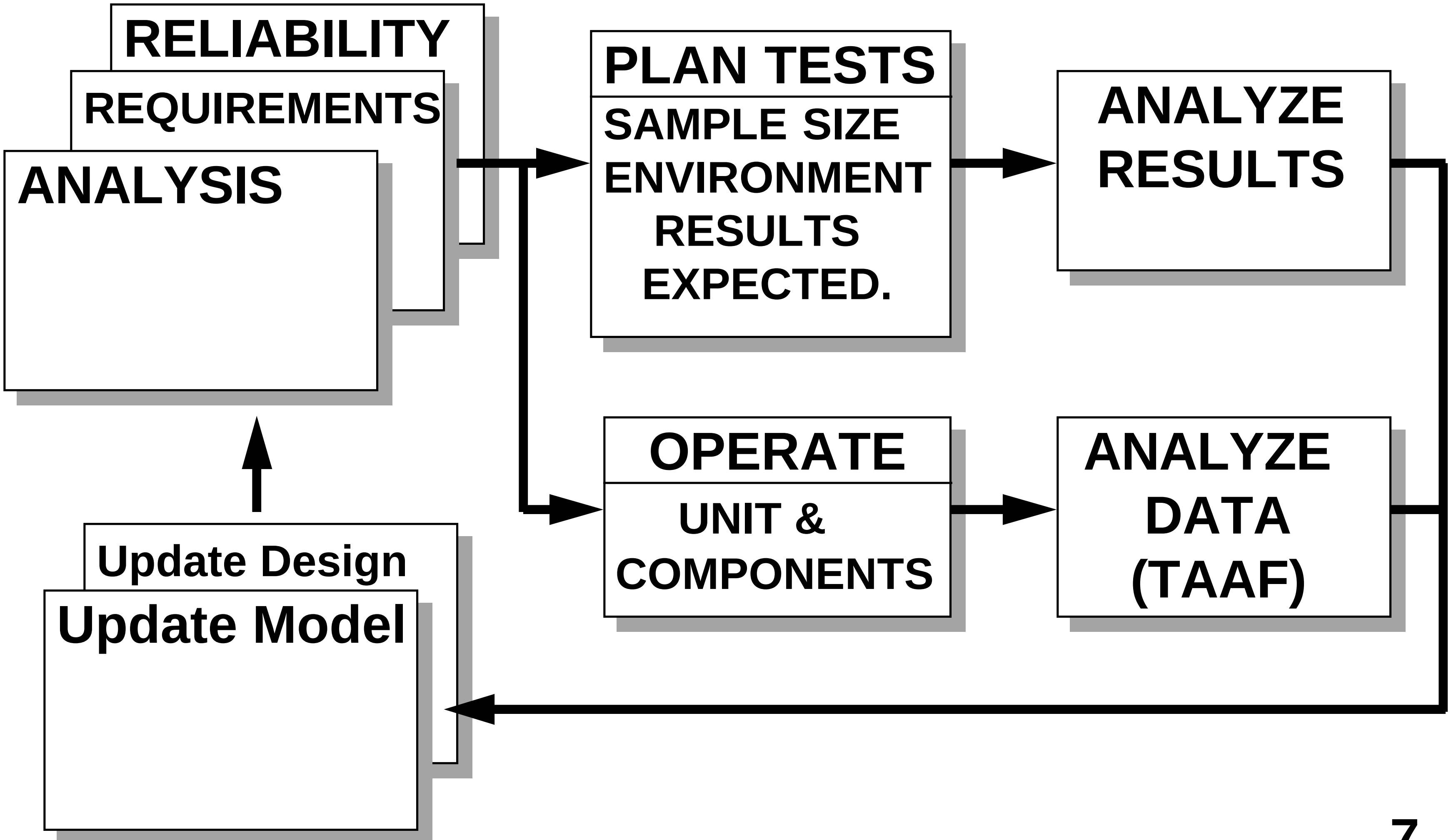
Testing OBJECTIVES:

- Explain (or perform):
- Why is it beneficial to test?
- What must be done before testing is started?
- Be able to categorize & explain types of tests.
- How is test data reduced and analyzed?
- What are the minimum test sample sizes?
- Apply Confidence limits.
- Apply Exponential & Weibull Distributions.

Outline--Testing

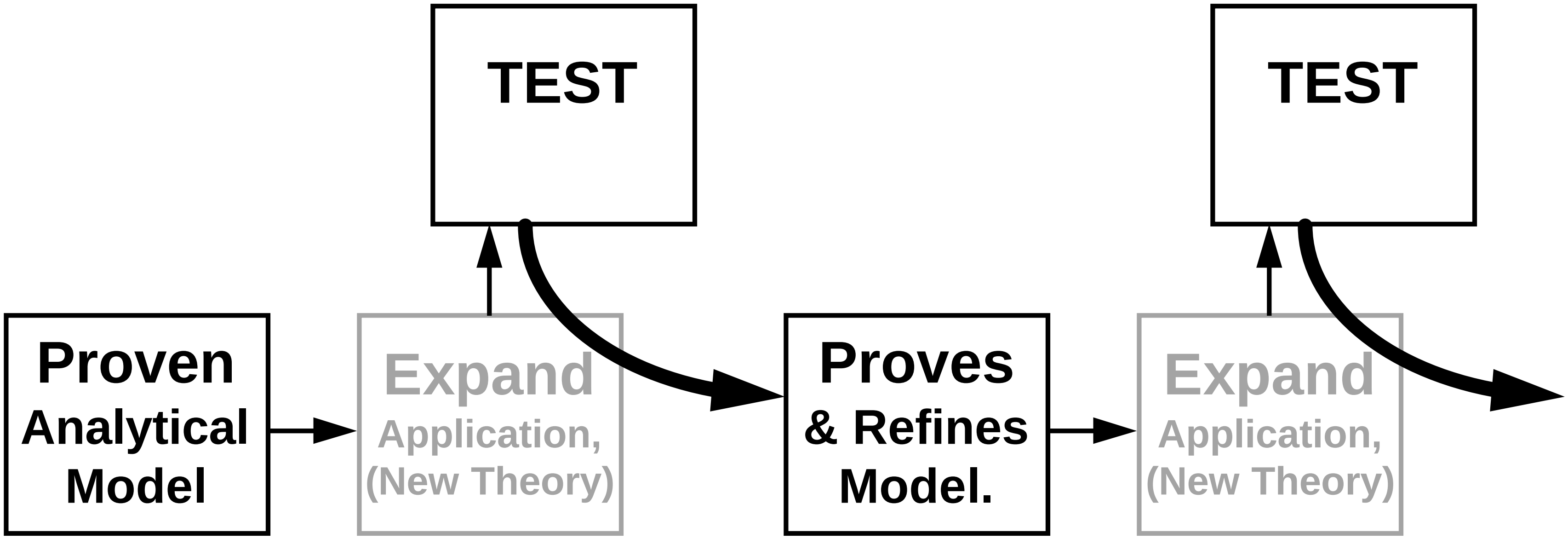
- Types of Tests
- Things to Consider
- Test Planning
- Analysis of Test Data
- Additional Information
  - Weibull Distribution
  - Analysis of Test Data with Suspended Tests
  - Confidence Levels

TESTING--System Interaction



TESTING--System Interaction

- Confirm Analytical Models & Design
- Extrapolated analytical models of componentry are greatly enhanced when confirmed by test data.



TYPES OF TESTS (typical classifications):

- Functional / Performance Tests
  - Engineering Performance Tests
  - Test, Analyze and Fix (TAAF)
- Environmental Tests
  - Environmental Stress Screening Tests (ESS)
- Reliability Tests
  - Sequential Life Testing
  - Sudden Death Testing
  - Fixed Length Testing
- Tests to Confirm Design/ Mfg. Process
  - Acceptance Tests
  - Attribute Tests
  - Safety Related Tests

Test, Analyze and Fix (TAAF)

- Rapid, iterative and informal test procedures used by designers during a development program to achieve reliability growth.
- Involves testing the equipment under simulated use environments to induce failures due to weak design or inadequate parts.
- The failures are analyzed.
- Corrective action is promptly taken for each failure to fix the discovered problem and to prevent recurrence while the test continues.

Environmental Stress Screening Tests (ESS)

- The process of submitting a group of like items to an application of physical climatic stresses in order to identify and eliminate defective, abnormal or marginal parts and manufacturing defects.

Sequential Testing

- **Sequential Life Testing. Multiple sampling reliability test based on binomial probability which is planned so that neither the number of failures nor the time required to reach a decision on the component reliability are fixed in advanced but depend on cumulated results (a.k.a. Requirements Qualification Tests or RQT).**
- **Sequential Testing is a process of continually assessing test results to arrive at a go/no go decision with a minimum of testing.**
- **At decision points the alternatives are accept, reject, or continue testing.**
- **Sequential tests are used to verify the reliability of production on a sampling basis.**

Sudden Death Testing

- A form of failure terminated testing that is suspended when at least one item in each of a group of tested items fails.
- A large number of components are tested by dividing then into several groups with (typical) 5 or 6 components in each.
- Then the components in each group tested simultaneously until one component fails.
- At first failure, testing stops on remaining components in group.
- After there is a failure in each group the test ends

Fixed Length Testing

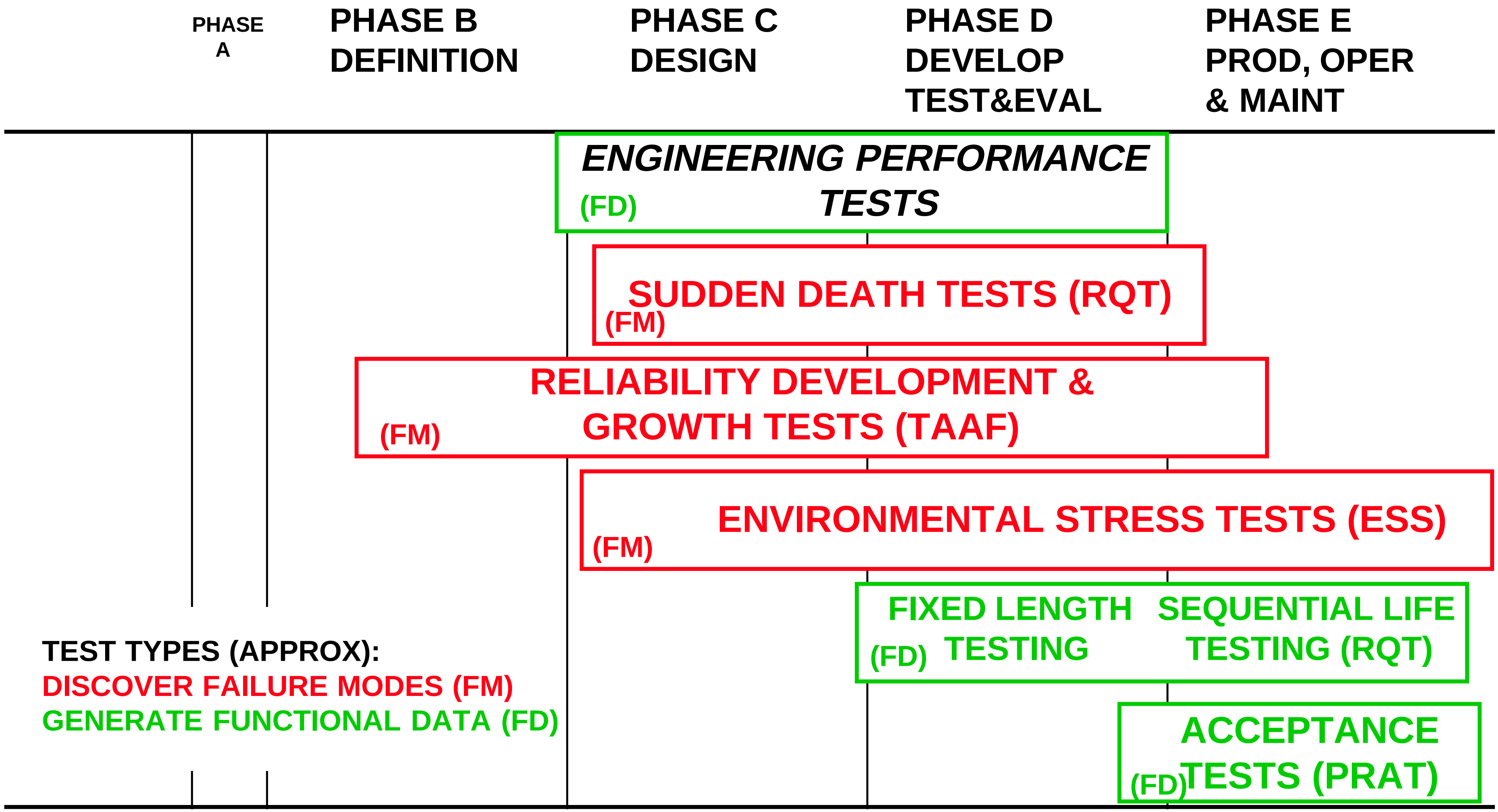
- Given failure data where not all samples have failed. These generate censored data (data representing incomplete life testing results).
- Some survived to end of test or were withdrawn. These generate suspended items (survived or removed).

Attribute/Acceptance Test Methods

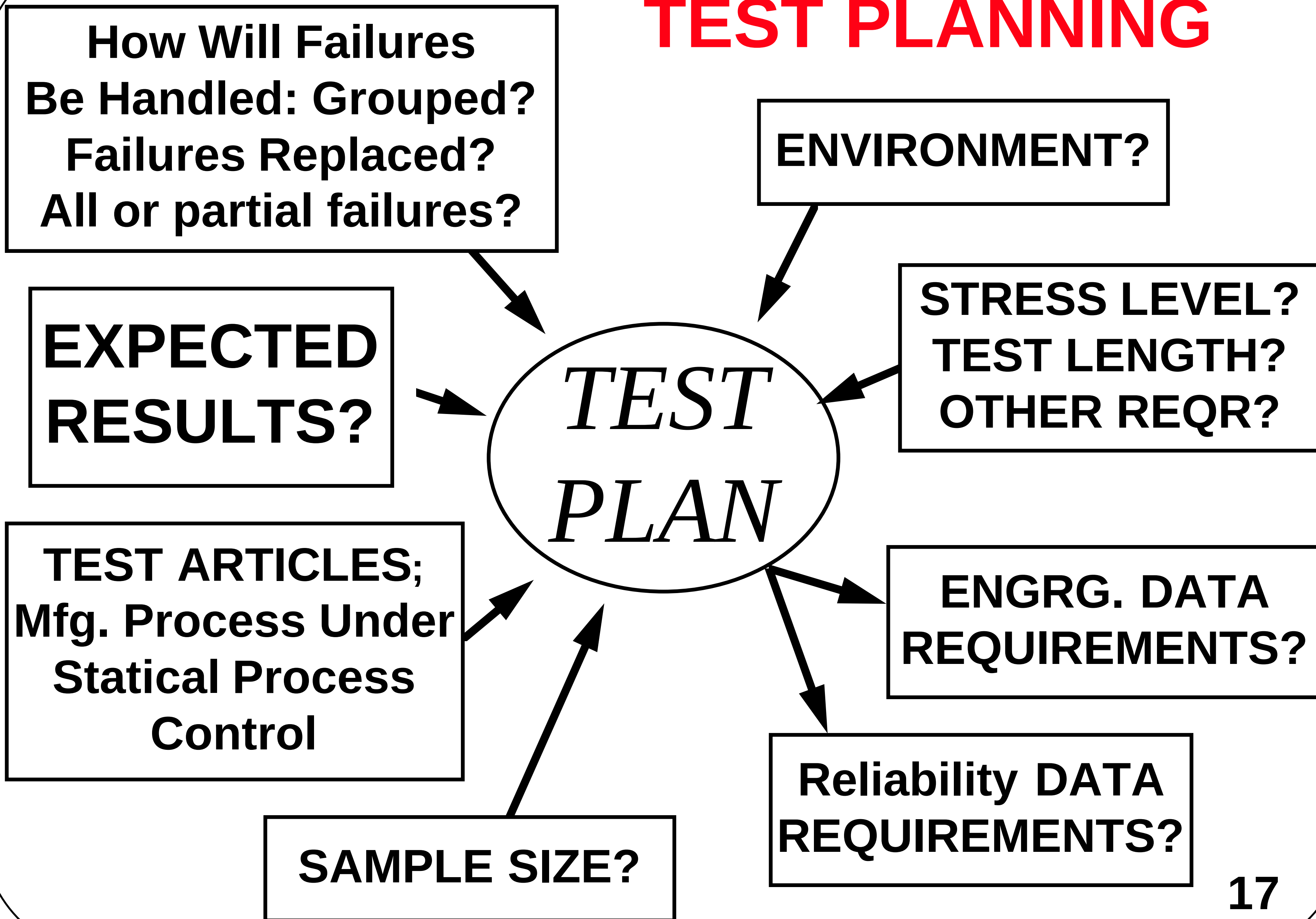
- **Attribute Tests: A test procedure to classify items under tests according to qualitative rather than quantitative characteristics (e.g. Go/NO-GO Testing).**
- **Loads and other environmental factors as well as engineering data maybe monitored.**
- **Acceptance Tests: A test to determine product conformance to design specifications passing being a condition of "acceptance" of the item.**
- **PRAT = Product Reliability Acceptance Test: performed to verify reliability during production where design, process, material variations could occur.**

Testing - Overview

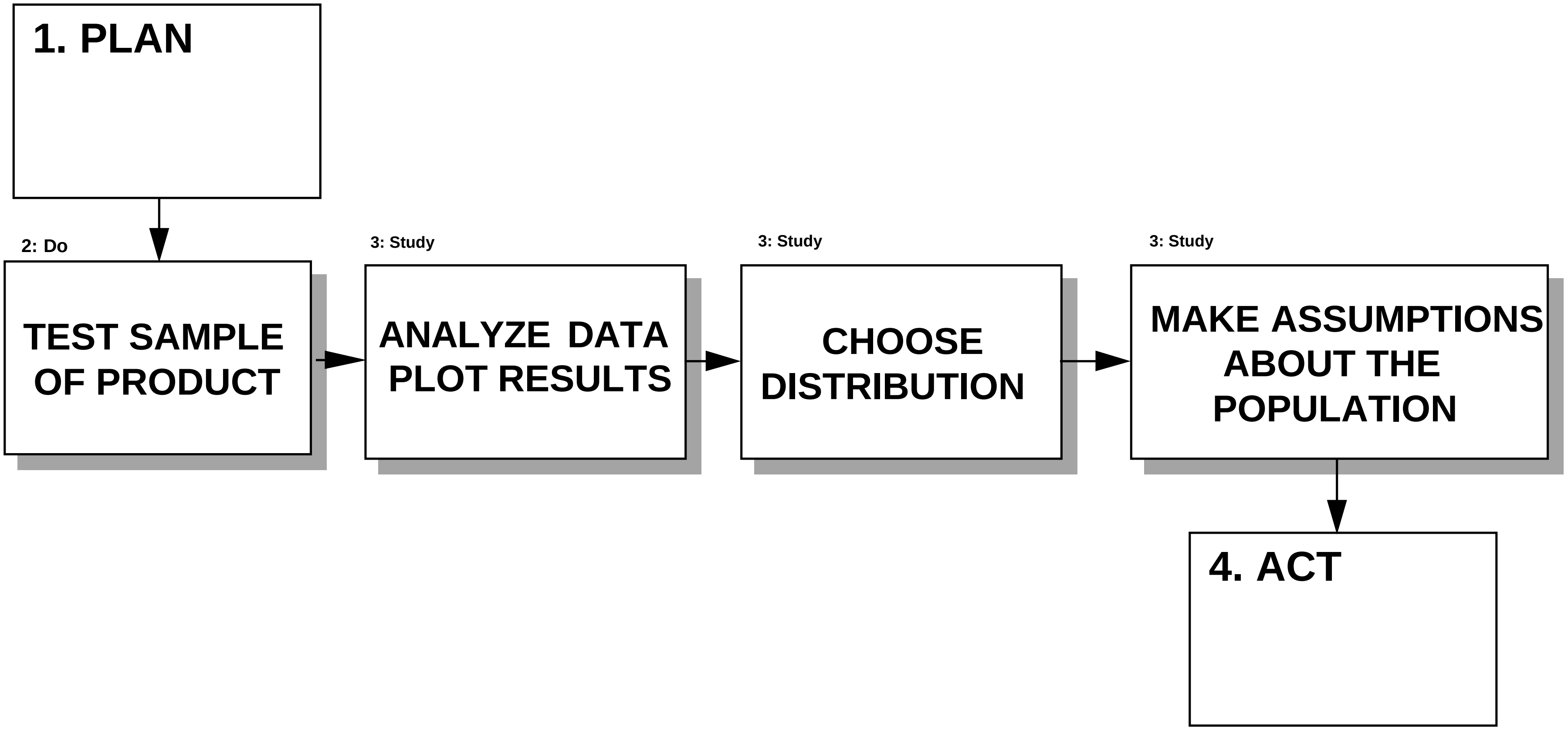
(typical time frames)



TEST PLANNING



TEST PLANNING



Things to Consider In Planning Tests: SAMPLE SIZE

(typical)

- For Normal Distribution analysis n >= 30 (otherwise Student t Distribution)
- If sample size is <=10, then median ranking technique should be used.
- For a Weibull Distribution analysis a minimum 7 is recommended by various sources.
- INDIVIDUAL COMPONENTS: 10 to several 100
- SUBSYSTEMS: a few to 20 or 30
- COMPLETE SYSTEMS: 1- 10

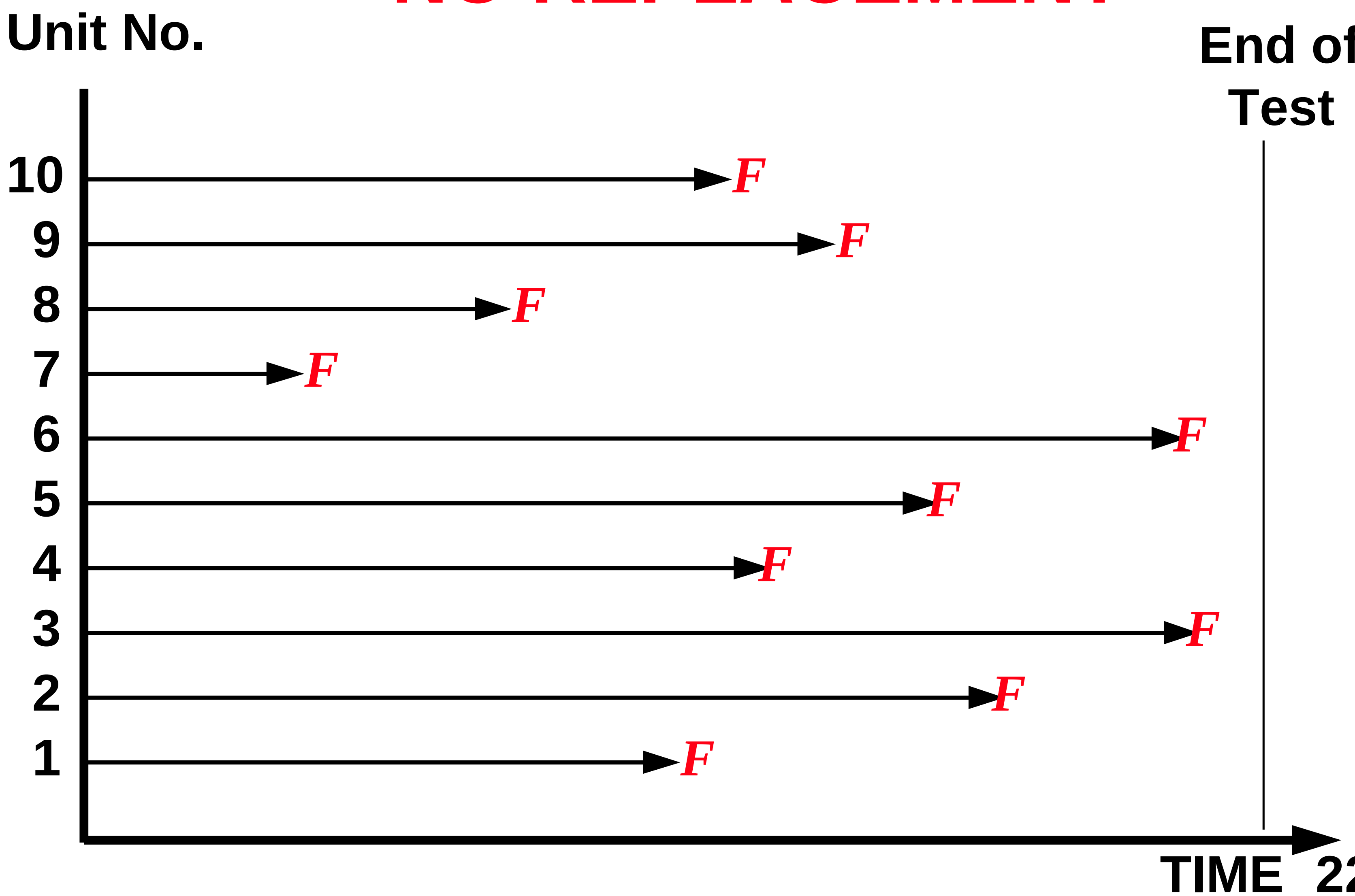
Things to Consider In Planning Tests: Selecting Test Articles & Process Variation

- Is there more than one vendor for this product?
- What is the range of production processes?
- Is the process in statistical control?
- Are there large lot to lot variation?
- Will all my test samples come from one lot?
- What manufacturing parameters are affecting quality and reliability?
- How can the process be improved?
- Have test articles failed some mfg. tests and/or have they been reworked?

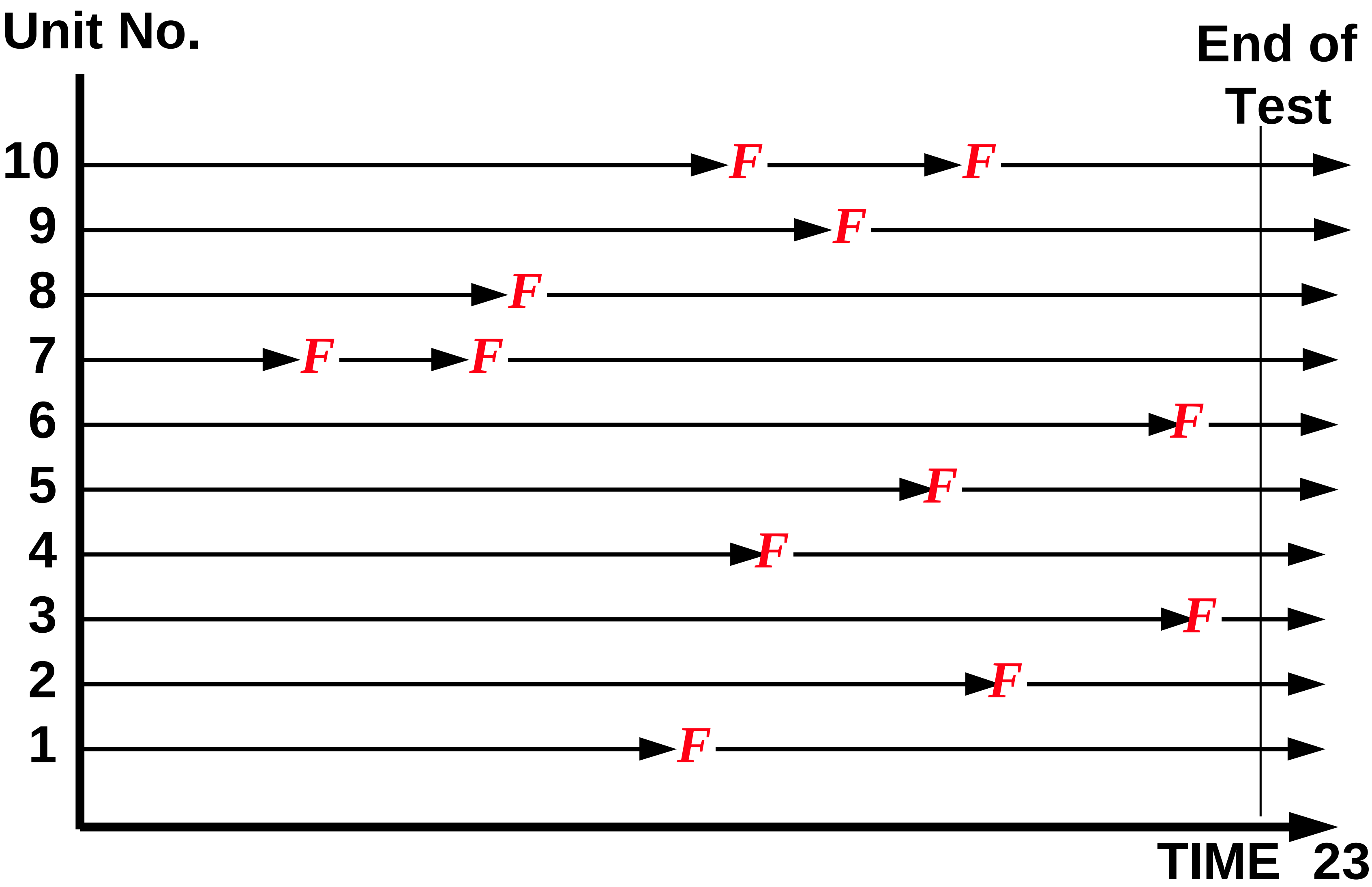
Things to Consider In Planning Tests: Expected Data & Results

- **What are my expected results/failure rates?**
- **Is the data grouped or ungrouped?**
- **What should be the sample size?**
- **Do I expect all of the unit to fail?**
- **Will failed units be replaced?**
- **What type of distribution might this data fit?**
- **Do I need to know MTBF? also Confidence Interval? or some Correlation Coefficient?**
- **Will there be multiple failure modes?**
- **What codes and standards need to be met?**
- **What contractual requirements need to be met?**

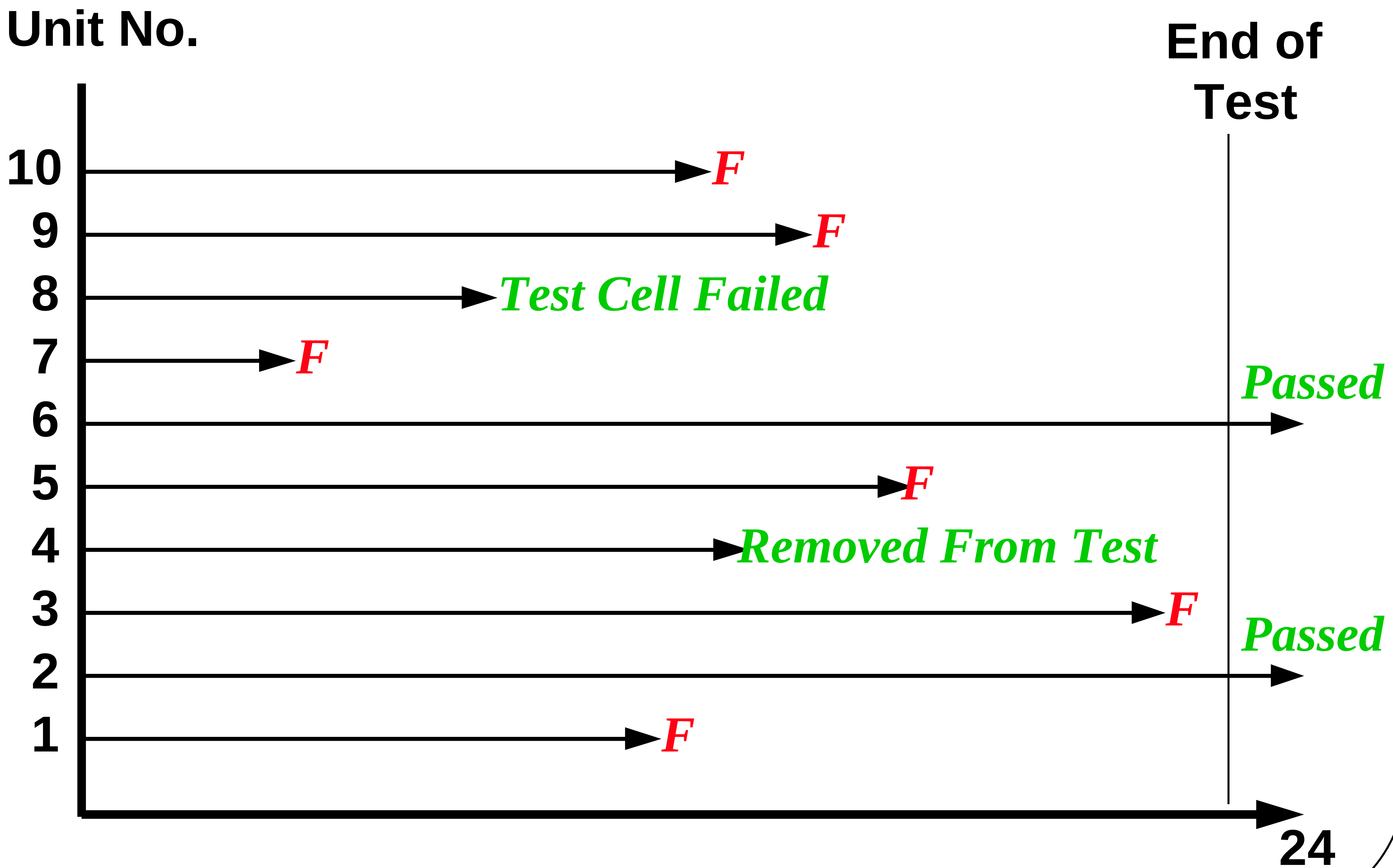
Handling Failures: ALL UNITS FAIL NO REPLACEMENT



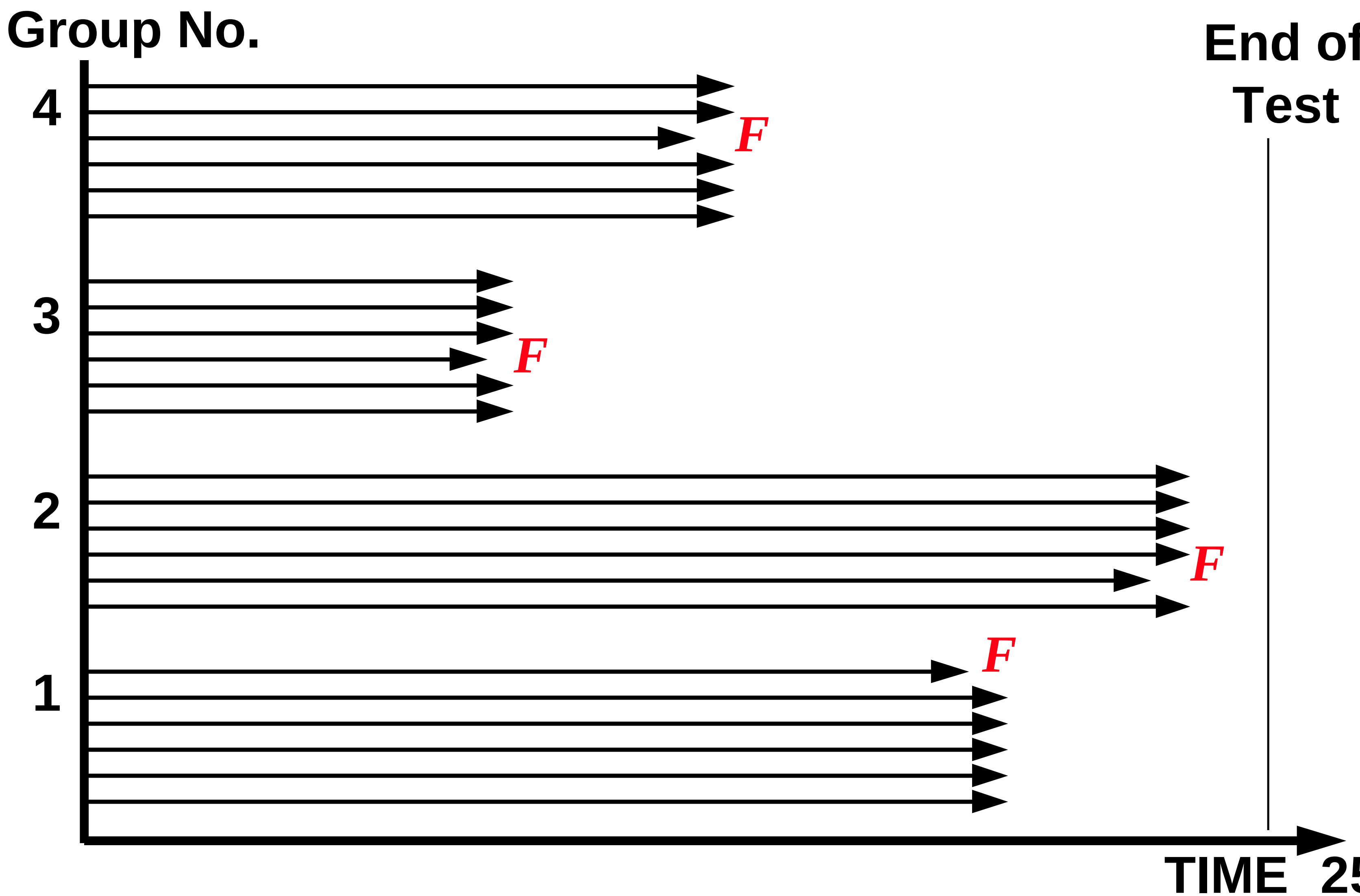
Handling Failures:
UNITS REPLACED WHEN FAILURE OCCURS



Handling Failures: PARTIAL FAILURES AND SOME UNITS REMOVED



Handling Failures: GROUPED DATA



TEST PLANNING:
OTHER REQUIREMENTS

- Model allocation (How many test articles are available?; What componentry is available for test?).
- Requirements for facilities and fixturing.
- What is the test and failure reporting system?
- Which test are to generate failures?
- What engineering specifications need to be verified?
- Before the test starts, what should the burn-in/run-in be.
- Should testing be conducted at an elevated stress level?
- What is the expected length of the test?

Test Planning -- Environmental Stress Tests

(and environments for other types of tests)

- **Define all environments (for each mission phase):**
- **Consider: temperature, vibration, shock, humidity, cyclic and static loads, power input (including transients), static electricity, electromagnetic interference (EMI), contamination, salt spray, fungus or bacteria, animals, bugs. etc.**
- **For space environments etc. also consider: acoustic load, radiation, ambient pressure or vacuum, atomic oxygen, electromagnetic pulse (EMP).**

Test Planning -- Environment
(con't)

- **Define all mission phases:**
- **Consider: Testing, storage, packaging, shipping, final checkout, launch packaging, launch, storage in space, operation, stowing, return, other testing;**
- **Define all operational modes:**
- **Consider: Unpowered, standby (various power levels) and levels of active operation.**

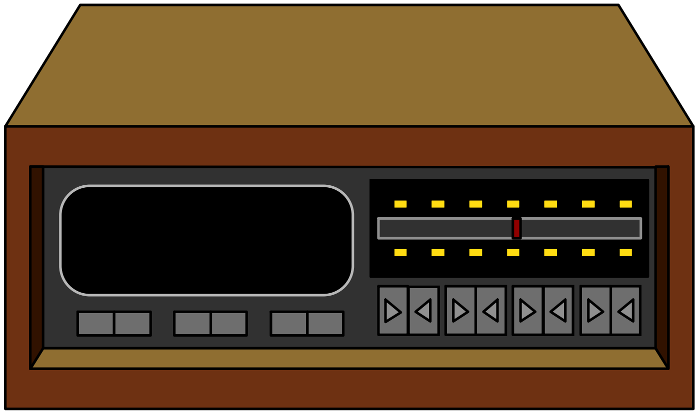
Test Planning -- Environment

(continued)

- Sequence of loading which duplicates actual use is critical (e.g. for fatigue analysis).
- Find out how the customer actually uses the product!!
- Operational modes during each mission phase.
- Vibration, especially launch, EMF, storage protection from humidity, vibration, voltage pulses & static elec.
- What engineering data will be taken during the test (e.g. pressure, temperature, displacement, strain, etc.)? For what purpose? How will it be used? How will it be recorded and analyzed? What accuracy and frequency are required?
- What mathematical functions is expected to describe the resultant data?

P-MISSION PHASES x ENVIRONMENT x OPERATIONAL MODES

EXAMPLE--Testing Mass FLow Controllers



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EXAMPLE--Predict Environment

- **Launch**
- **Return**
- **Test**
- **Ship**
- **Operate**
- **Standby**
- **Off**
- **Store(C)***
- **Store**

***Storage Under Controlled Conditions**

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Example--Environmental Analysis

- Phase____________ How Packaged ____________
- Unit_______ Make _______ Model _____S/N _____
- Vib. x _____________
- Vib. y _____________
- Vib. z _____________
- Acoustic _____________
- Temp _____________
- Humidity _____________
-
- Analysis by:____________ Date:_____

ANALYZING DATA: Verify:

- Did engineering data meet expected results?
- Did the environment stay within specifications?
- Did elevated stress levels stay within specifications?
- Were anomalies properly reported and investigated?
- How did the data compare with historical test data?
- Did the predicted math models properly define results?
- Were other results as expected in the test plan?
- Did the unit fail in the manner expected?
- Was the reliability data as expected?
- What is the failure rate?
- How can the unit be improved?

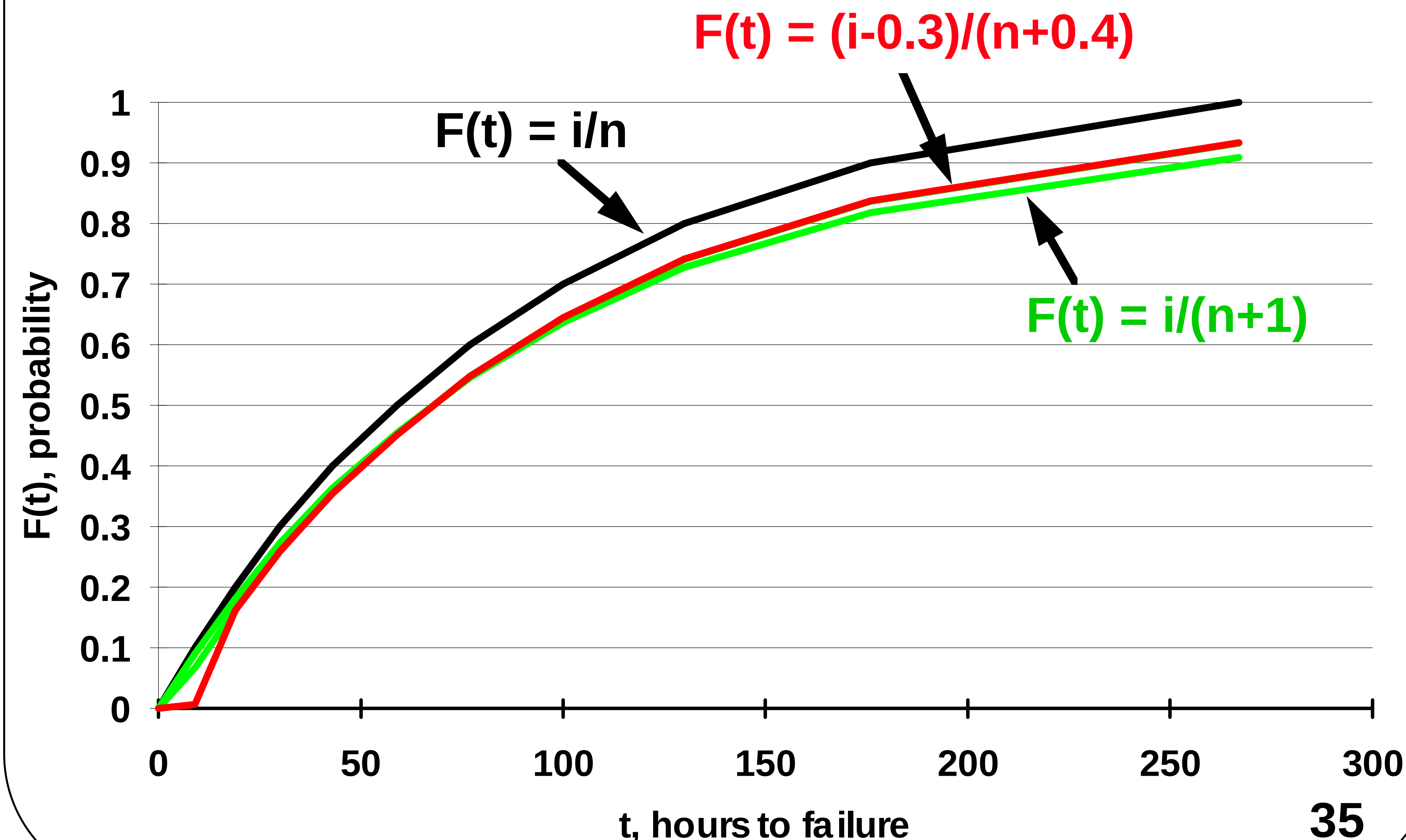
ANALYZING DATA

Assume individual data (Not grouped data). Assume all units failed & none were withdrawn.

- **Rank data in order of failure time**
- **Calculate cumulative distribution function, $F(t_i)$ for each data point.**
  - **Assume $F(t_i) = i / n$ *??? No!***
  - **Use $F(t_i) = i / (n+1)$ *when* n > 10.**
  - **Use $F(t_i) = (i-0.3)/(n+0.4)$ *when* n <= 10.**

Terminology: *Mean rank* refers to the expression, $i/(n+1)$. *Median rank* refers to the expression, $(i-0.3)/(n+0.4)$

F(t) = i /n vs. F(t) = i /(n+1) etc.



ANALYZING DATA (continued)

- **Plot the data: failure times vs. $F(t_i)$ on graph paper with the x-axis as time (or cycles to failure) and the y-axis as cumulative percent (or probability) failure.**
- **Draw a line of best fit through the points.**
- **Calculate $R(t)$ and $h(t)$ and plot on regular graph paper (optional).**
- **To test for exponential distribution: Repeat the plotting of failure time vs. $1 / [1-F(t_i)]$ *on* log-normal paper (derivation follows).**

ANALYZING DATA (continued)

- **Where:**
- ***$F(t_i)$ =*** *cumulative distribution function*
- ***i =*** *component number (rank order)*
- ***n =*** *total number of samples*
- ***R(t) =*** *reliability distribution function*
- ***f(t) =*** *probability distribution function*
- ***h(t) =*** *hazard function*

EXPONENTIAL DISTRIBUTION?

Cumulative Distribution of exponential distribution is given by:

$$F(t)=1-e^{-\lambda t}$$

rewriting we have:

$$1-F(t)=e^{-\lambda t}$$

taking the log of both sides we have:

$$\ln\,[1/(1-F(t))]=\lambda t$$

plotting *1/(1-F(t))* on semi log paper and getting a straight line indicates an exponential distrb.

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Example: The failure time of 10 mass flow controllers (MFC-11) are recorded to be 7, 16, 27, 40, 52, 71, 91, 115, 153, 206 hours. Use $F(t_i) = (i-0.3)/(n+0.4)$.

i	t	$F(t_i)$	$R(t_i)$	$h(t)$	$1/[1-F(t_i)]$
1	7				
2	16				
3	27				
4					
5					
6					
7					
8					
9					
10					

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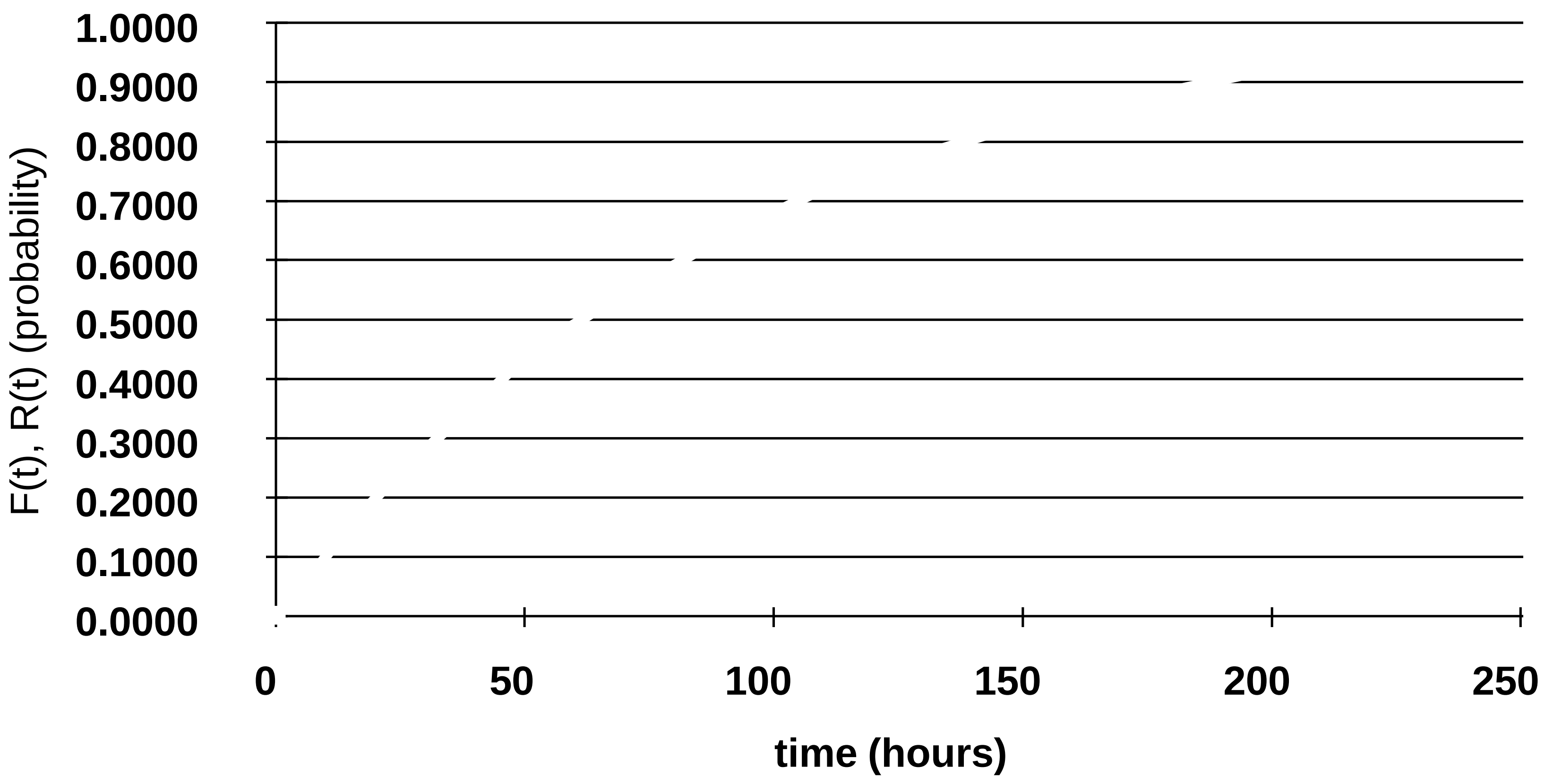
Example (con't) -- PLOT CDF & RF



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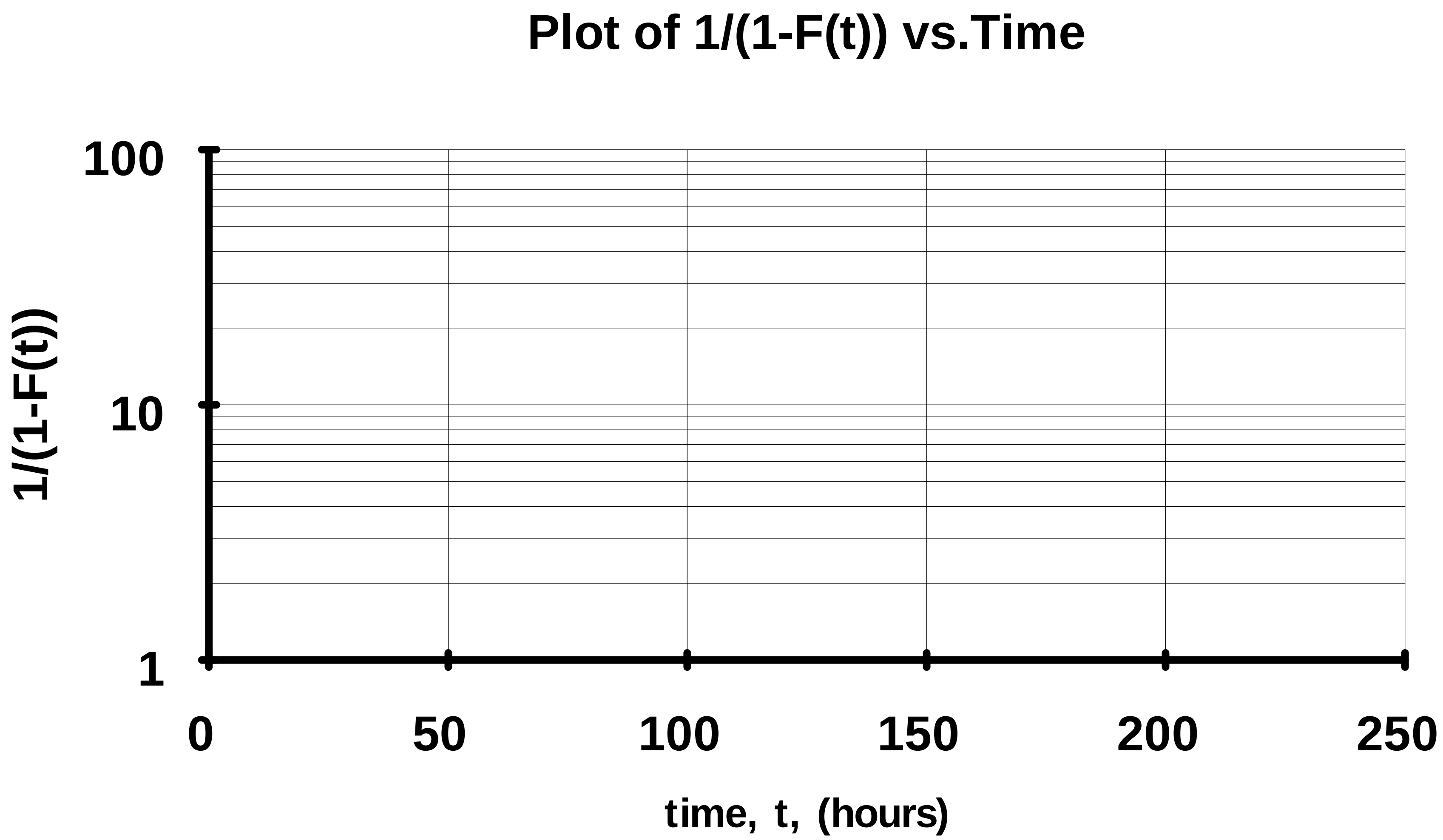
Example (con't).-- PLOT OF DATA:



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CONCLUSIONS

- Testing reduces development costs and total costs of ownership because of a complete prove-out of the product.
- There are a variety of testing procedures which can be applied to the reliability assessment, TAAF, PRAT, ESS, RQT and R&D (Engineering) tests.
- Minimum sample size and the confidence level it generates needs to be carefully evaluated.
- Test planning must include a careful duplication of the real environment the test article will experience in the real world. 1 of 2

CONCLUSION: To access reliability we need:

- **Test Procedure and Sample Size**
- **Operating conditions in lab must simulate actual conditions**
- **Major factors are environment, power-on, power-off, power-cycling, preventative maintenance, operator tasks, field tolerance limits.**

END

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- **Example:** The failure time of 10 mass flow controllers (MF-11b) are recorded to be 33, 69, 109, 154, 206, 268, 342, 436, 565, 771 hrs. Use $F(t_i) = (i\text{-}0.3)/(n+0.4)$.

i	*t*	$F(t_i)$	$R(t_i)$	$h(t)$	$1/[1-F(t_i)]$
1	33	______	______	______	______
2	69	______	______	______	______
3	109	______	______	______	______
4	______	______	______	______	______
5	______	______	______	______	______
6	______	______	______	______	______
7	______	______	______	______	______
8	______	______	______	______	______
9	______	______	______	______	______
10	______	______	______	______	______

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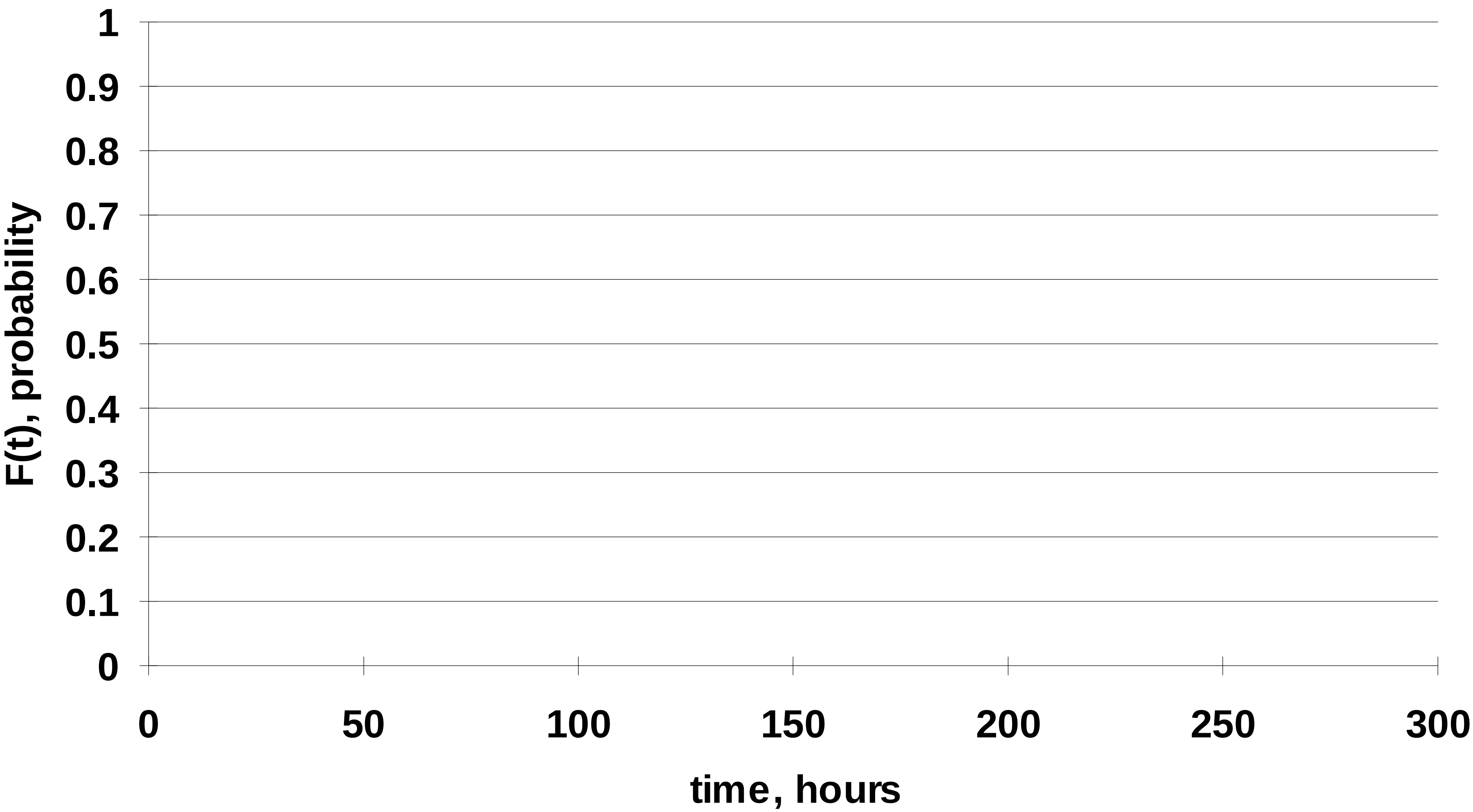
Example (con't) -- PLOT CDF & RF



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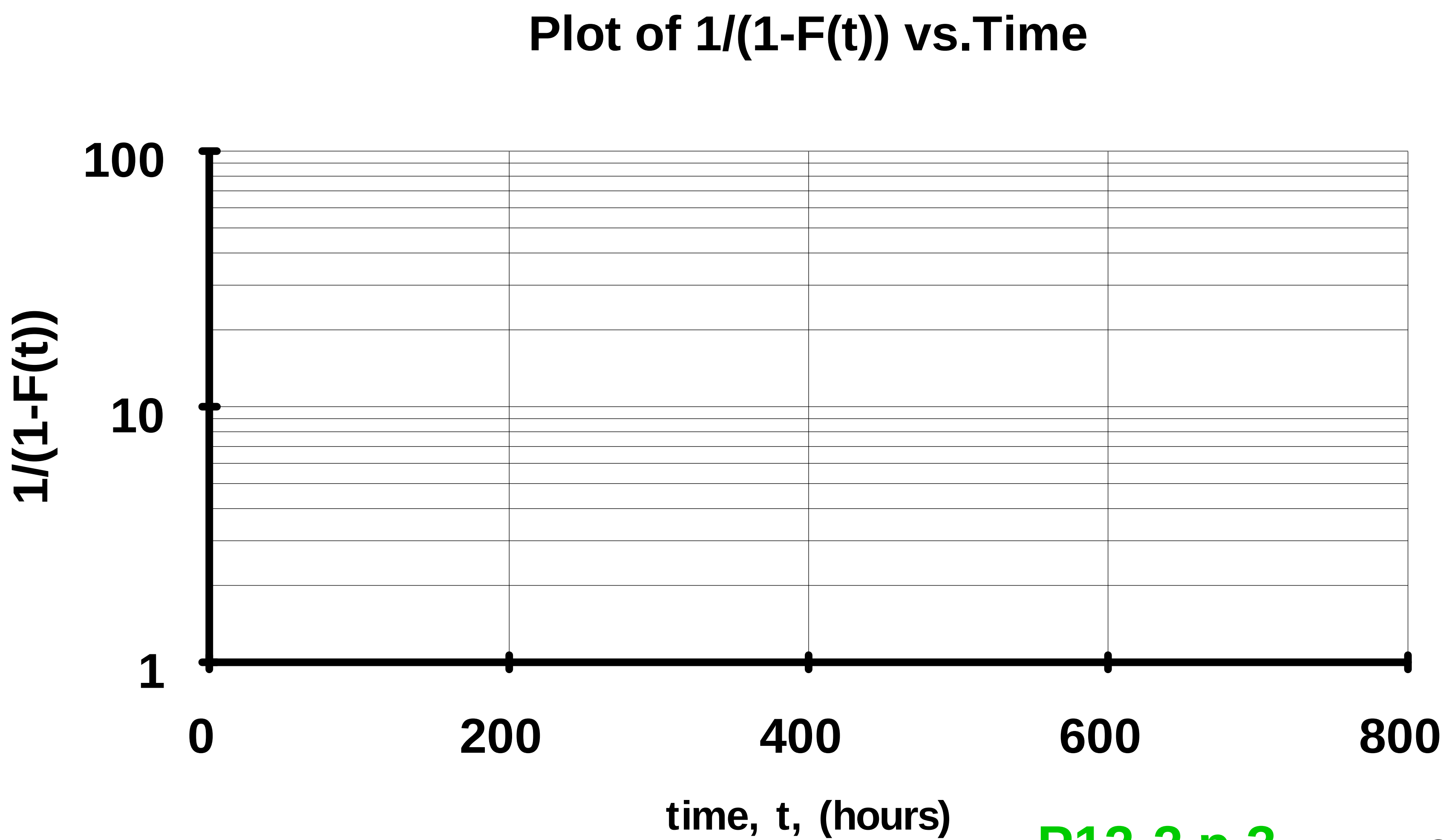
Example (con't).-- PLOT OF DATA:



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